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INFLUENCE OF GRAPHENE NANO FILLER ON THERMAL AND DYNAMIC MECHANICAL PROPERTIES OF GLASS FIBRE POLYMER COMPOSITES

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ABSTRACT

Enhancement of various nano fillers in the glass fibre polymer composites has been studied in many fields of science and engineering with the aim of strengthening glass fibres and obtaining better performance with addition of nano fillers. To study and evaluate the visco elastic parameters in composites, dynamic mechanical analysis technique was adopted. In the present work, glass fibre reinforced epoxy composites with different graphene nano filler loadings were fabricated using the hand lay-up technique, by incorporating different graphene weight percentage (2%, 4%, 6%) of glass fibres into the epoxy matrix. The fabricated graphene reinforced glass fibre polymer composites were subjected to a series of dynamic mechanical tests with varying test frequencies (0.5 Hz, 1 Hz, 2 Hz, 5 Hz and 10 Hz) over a range of testing temperatures (20^0 to 150^0 C). Various dynamic mechanical properties such as storage modulus (E'), Loss modulus (E'') and Glass Transition temperature (T_g) were predicted at different test frequencies (0.5 Hz, 1 Hz, 2 Hz, 5 Hz and 10 Hz). It was observed that thermal stability was found to improve on increase in graphene nano filler weight percentage in the glass fibre polymer composites. Moreover, it was noticed that, it had a significant effect on dynamic mechanical behaviour of graphene reinforced glass fibre polymer composites by varying test frequencies.

KEYWORDS: Nano Filler, Graphene, DMA & Glass Fibre

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Original Article

INTRODUCTION

Graphene Nano powders, an allotrope of carbon is the strongest material ever known for its amazing characteristics. Graphene is harder than diamond yet more elastic than rubber; tougher than steel yet lighter than aluminium. Graphene is known to be the basic building blocks of graphitic materials and it is very attractive for the fabrication of polymer composites that is carried out through hybridizing graphene nano powders with glass fibres [1]. The enhancement of Graphene nano fillers into the glass fibre with epoxy resin to fabricate polymer composite laminates with improved mechanical properties is gaining attention in the recent years. Graphene nano filler has become a strong competitor compared to their allotropes such as single walled and multi walled carbon nano tubes due to their advantages of low density, renewable nature and biodegradability [1, 6]. In earlier years, various natural fillers such as Doum palm shell [2], coconut shell [3], sisal [4, 14] and Egg shell [5] were exploited with polymer composites to improve the mechanical performance. The rising demand for new materials with low density and environment friendly has led to the study of new glass fibre polymer composites containing easily available fillers such as multi walled carbon nano tubes and graphene [6]. The dynamic mechanical analysis method which is used for manipulating data helps in defining the thermal and mechanical properties of glass fibre polymer composites [7]. With a controlled temperature and frequency in dynamic mechanical analysis, a sinusoidal force is applied to the input to measure sinusoidal deformation i.e., visco elastic properties of glass fibre polymer composites [8, 13]. Both elastic and vicous properties are exhibited during the test. To understand the visco elastic behaviours, an

example of bouncing a ball can be taken. When a ball is bounced at a certain height from the ground, the ball retains only upto a certain height and that is regarded as elastic response i.e. storage modulus. The energy loss in internal motion is referred as viscous property i.e., Loss modulus [9,10]. The bouncing behaviour of a ball depends on its visco elastic properties. In general, the storage modulus (E') refers to the stiffness of material which is caused and related to the reversible "in phase" response and the Loss modules (E") refers to the oscillation energy, which is converted into heat energy related to the irreversible "out of phase" response [11, 14]. The deviation in stress and strain in Dynamic Mechanical Analysis (DMA) is the loss factor or phase shift (Tan δ). It is the ratio of loss modulus to the storage modulus.

$$\text{Tan } \delta = E''/E'$$

This characterizes the mechanical damping or internal friction of a visco elastic system [12]. The visco elastic properties namely material stiffness, glass transition temperature and damping factor are obtained from storage modulus (E'), Loss modulus (E") and Tan delta (δ) curve. In the present work, graphene nano filler enhanced glass fibre reinforced polymer composites are subjected to varying frequencies (0.5 Hz, 1 Hz, 2 Hz, 5 Hz and 10 Hz) over a range of testing temperatures (20^0 to 150^0 C) and visco elastic properties are predicted with varying nano filler percentage weight ratios.

MATERIALS AND EXPERIMENTAL METHODS

Materials

Glass fibres were used as reinforcement and epoxy resin LY5561 with corresponding curing agent i.e., hardener HY951 was used as matrix in fabrication of polymer composites. Graphene powders with 99.5% carbon purity are enhanced with glass fibre composites in different weight ratios. Glass fibre, epoxy matrix and graphene powders were purchased from the local source. Epoxy resin, curing agent (Hardener) and graphene powders were mixed in the ratio of 10:8:1 to make the matrix as recommended by the manufacturers.

Fabrication of Graphene Enhanced Glass Fibre Composites

The composites were manufactured by reinforcing directionally wovened glass fibre into epoxy resin using hand lay-up technique. Before reinforcement, the matrix material i.e., epoxy resin is mixed up with curing agent and appropriate weight percentage of graphene nano fillers with an ultrasonicator. The hardener assisted in easy removal of composite from the mould after curing. Specimens after curing were cut as per ASTM standards to carry out DMA test.

Dynamic Mechanical Analysis

ASTM standard ASTM D5023 was followed to carry out the DMA test with the specimens fabricated in dimensions of 50 mm x 12 mm x 3 mm. Standard dynamic mechanical analyzer was used with varying frequencies (0.5 Hz, 1 Hz, 2 Hz, 5 Hz and 10 Hz) over a range of testing temperatures (20^0 to 150^0 C) to experimentize various visco-elastic properties of glass fibre polymer composites.

RESULTS AND DISCUSSIONS

Effect of Temperature on Storage Modulus with varying Graphene weight Percentage in Glass Fibre Reinforced Polymers (GFRP)

Storage modulus (E') of different graphene % wt glass fibre polymer composites was plotted with varying temperatures which showed how the glass fibres with suitable graphene % wt GFRP were stiffer. Storage modulus of graphene

reinforced glass fibre composites were found to decrease, when weight percentage of Graphene in GFRP increased. The enhancement of graphene in glass fibre increased the stiffness of the matrix and hence better storage modulus was obtained with 6% graphene wt. GFRP. The peak value of E' occurred with 6% graphene wt GFRP. This shows that on increase in % weight of graphene in glass fibre matrix, stiffness increases. Alternatively storage modulus decreased with an increase in temperature, as stress of fibres gets reduced with an increase in temperature. The value of storage modulus is directly proportional to the ratio of matrix and nano filler (Graphene) bonding with the glass fibres.

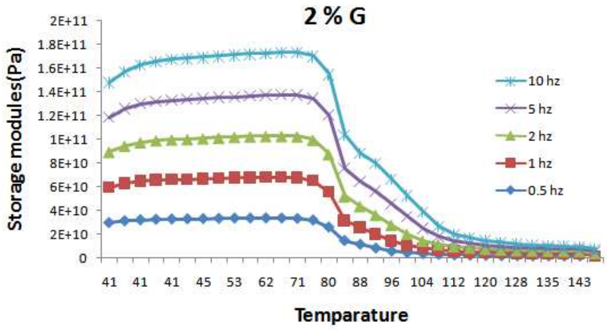

Figure 1: Influence of Temperature and 2% Weight Graphene Enhancement in GFRP on Storage Modulus.

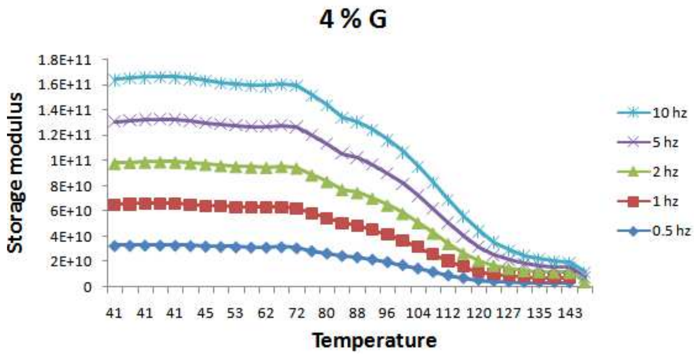

Figure 2: Influence of Temperature and 4% Weight Graphene Enhancement in GFRP on Storage Modulus.

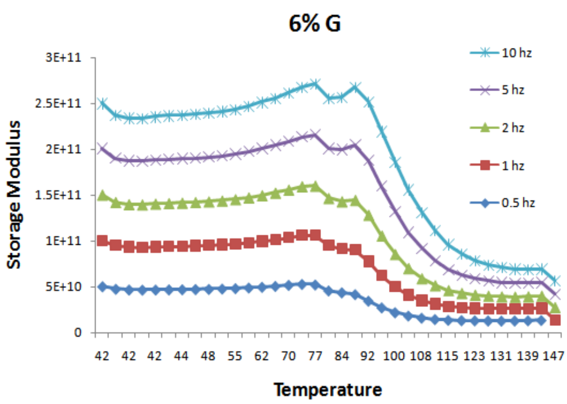

Figure 3: Influence of Temperature and 6% Weight Graphene enhancement in GFRP on Storage Modulus.

Effect of Temperature on Loss Modulus with Varying Graphene Weight Percentage in Glass Fibre Reinforced Polymers (GFRP)

The maximum energy unconfined by composite materials during deformation is termed as Loss modulus. The viscous response of polymeric composites depends on the motion of polymeric molecules in the composite laminates. The effect of graphene addition on loss modulus of the glass fibre composite is illustrated in the figure. The loss modulus increases to a certain extent and then decreases. The mobility of graphene reinforced GFRP is decreased as it improves the loss modulus and however it decreases as the temperature is increased. As the temperature is increased, the mobility of GFRP increases.

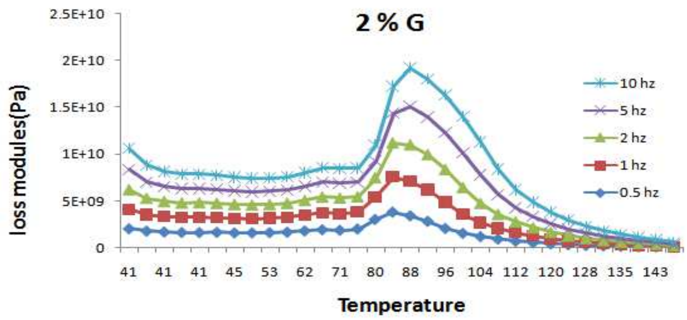

Figure 4. Influence of Temperature and 2% Weight Graphene Enhancement in GFRP on Loss Modulus.

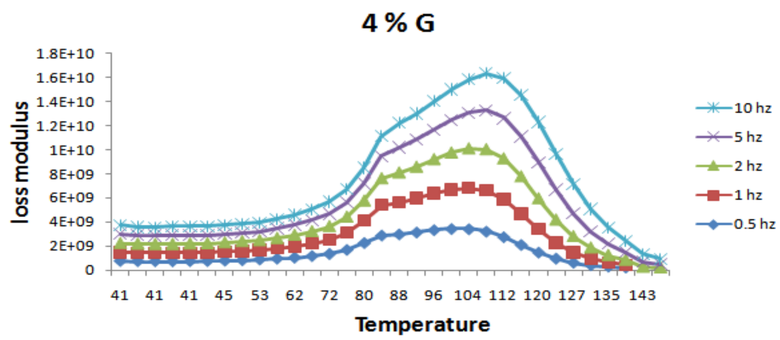

Figure 5: Influence of Temperature and 4% Weight Graphene Enhancement in GFRP on Loss Modulus.

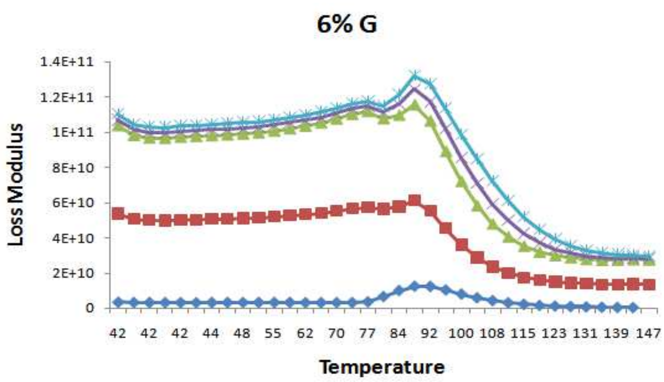

Figure 6: Influence of Temperature and 6% Weight Graphene Enhancement in GFRP on Loss Modulus.

Effect of Temperature on Damping Factor with Varying Graphene Weight Percentage in Glass Fibre Reinforced Polymers (GFRP)

The phase shift (tan δ) is termed as the damping factor and it measures the potential of GFRP to dissipate and absorbs energy. The balance between the elastic and viscous region in graphene reinforced GFRP is predicted. The impact resistance of the glass fibre composites is the damping factor which is regarded as the ratio of loss modulus to the storage modulus. Damping factor depends on adhesion between glass fibre and epoxy resin with nano filler matrix. To impart high impact strength of nano filler with GFRP, adequate reinforcement is required. With 2% graphene weight of fibre and matrix reinforcement, less damping effect is visualised in the graph shown with respect to temperature. When nano filler (graphene) percentage is increased at 6% wt, better adhesion between fibre and matrix is achieved and hence it has high impact strength. Effective stress transfer is achieved by better bonding between the fibre and the matrix. The phase shifting of T_g occurs (increase to decrease) on increase in temperature of graphene enhanced glass fibre polymer composites. The mobility of polymer composites is decreased in high percentage weight of graphene enhanced GFRP. The values of T_g obtained from Tan δ for GFRP with different % weight of graphene is shown in figure.

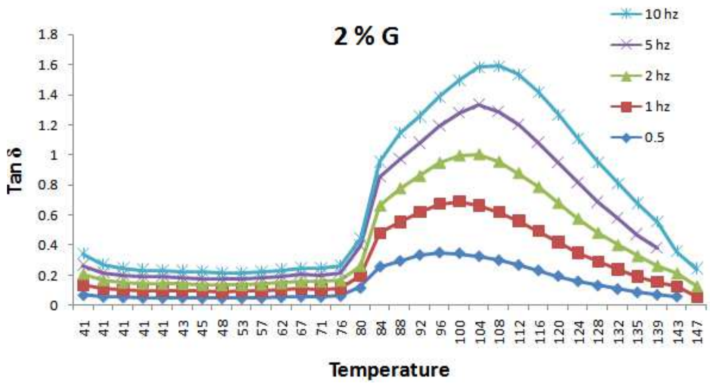

Figure 7: Influence of Temperature and 2% Weight Graphene enhancement in GFRP on Damping Factor.

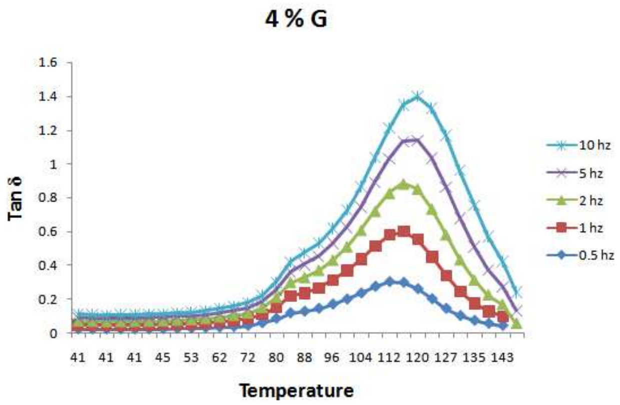

Figure 8: Influence of Temperature and 4% Weight Graphene Enhancement in GFRP on Damping Factor.

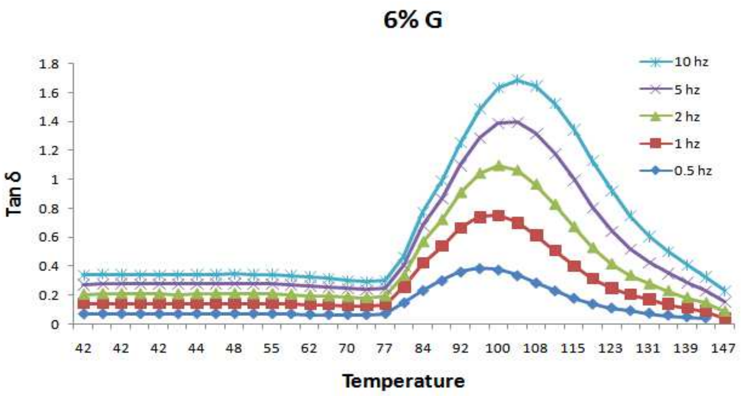

Figure 9: Influence of Temperature and 6% Weight Graphene Enhancement in GFRP on Damping Factor.

CONCLUSIONS

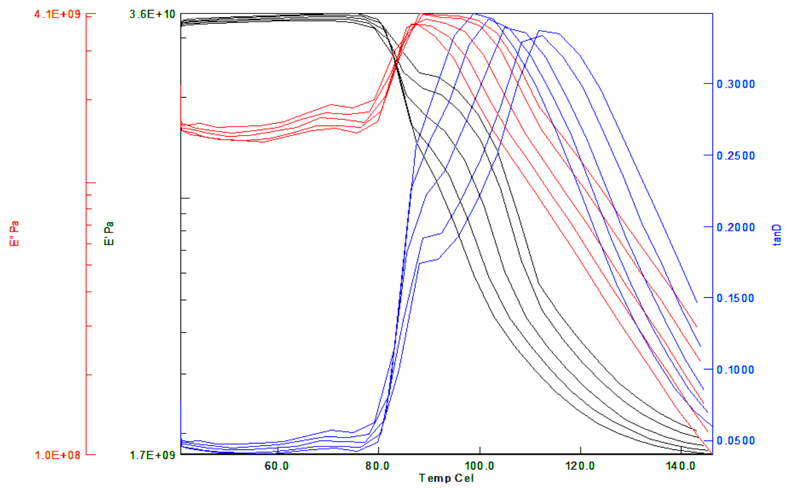

Figure 10: Influence of Temperature on Visco-Elastic Properties with 2% Weight Graphene Enhancement in GFRP.

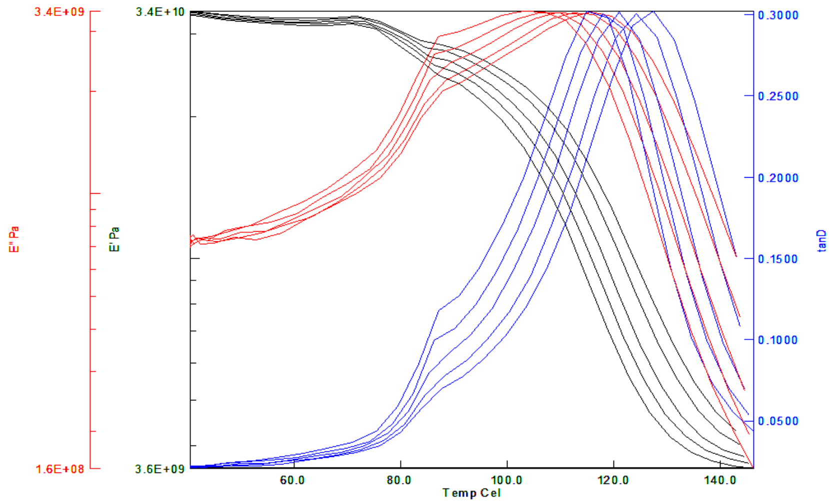

Figure 11: Influence of Temperature on Visco-elastic Properties with 4% Weight Graphene enhancement in GFRP.

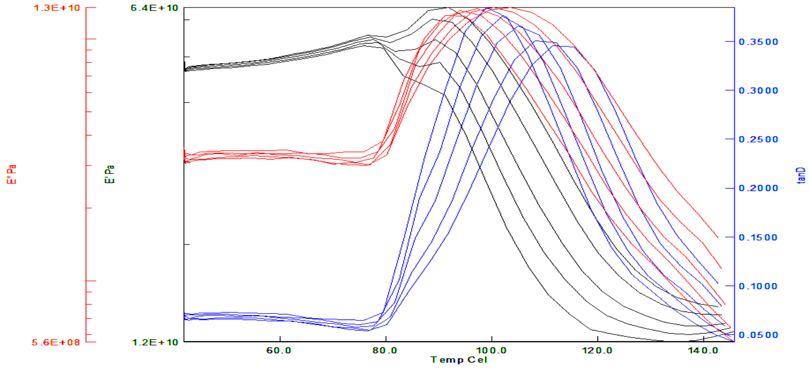

Figure 12: Influence of Temperature on Visco-Elastic Properties with 6% Weight Graphene Enhancement in GFRP.

The graphene enhanced glass fibre reinforced polymer composites investigated with varying frequencies over a temperature range showed that the addition of nano filler to glass fibres to epoxy matrix have better effect on thermal and dynamic properties of composites. The glass transition temperature (T_g) was found maximum for the glass fibre composites having 6% wt. Grahene nano filler. Storage modulus increased with the increased frequencies and reduced on increasing temperature. It is evident from the figure that the value of storage modulus was found to be peak at higher frequency i.e., at rubbery region. Beyond 100^0 C, nano filler content intends to reduce the loss modulus as nano fillers do not have any role in reinforcement of matrix after a certain increase in temperature. Better interfacial bonding is achieved between fibre and the matrix as it is observed from better increase in storage modulus and decrease in loss modulus. Thermal stability of the composites was found to reduce with an increase in frequencies. Thus, on increase in percentage weight of graphene nano filler, better reinforcement and adhesion is achieved between the fibre and the matrix.

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